AN APPARENT INFLUENCE OF THE EARTH ON SOLAR PROMINENCES

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ABSTRACT. In this paper a statistical study has been made of Kodaikanal observations of solar prominences during the period 1913-37 and it has been found that the annual variations of the mean daily areas, the mean daily heights and of the mean daily bases of prominences at the limb correspond to the variation of the earth's distance from the sun in the course of the year. In particular it has been found that the maximum of the mean daily area at perihelion and the minimum at aphelion differ from each other by about 9.6 per cent of the maximum. This has been shewn to be evidence of the existence of a terrestrial influence on solar prominences. The effects of planets other than the earth have also been examined and it has been concluded that they cannot be appreciable. It has been tentatively suggested that the observed influence of the earth on prominences may well be the result of a tide-raising force which varies inversely as the cube of the distance between the earth and the sun.

The possibility of an influence of the earth and of other planets on solar prominences has been considered by several workers[1–7] in the past; their methods of investigation have been varied, but they have been concerned chiefly with the distribution of the numbers and areas of sunspots and of faculae on the eastern and western sides of the central meridian and the numbers and areas of prominences on the eastern and western limbs of the sun. These investigations have, however, led to conflicting results and in most cases their results cannot be regarded as conclusive. It is not easy to decide whether this inconclusiveness is due to the insufficiency of the observational material used or due to other causes. In any case it seemed to us desirable to investigate the problem afresh by examining a uniform series of data of prominence areas extending over as long a period as possible and by employing a somewhat different method.

EARTH'S INFLUENCE AND DISCUSSION OF AVAILABLE PROMINENCE DATA

If the earth exercises any influence on solar phenomena it is most likely to be of a gravitational nature and one may reasonably expect this influence to manifest itself most when the earth is nearest to the sun and least when it is farthest away from it. During the course of its annual revolution the earth comes nearest to the sun in January and goes farthest from it in July at the epochs of perihelion and aphelion respectively. We may accordingly expect the areas of prominences to show a maximum in January and a minimum in July or *vice versa* according as the earth exercises an enhancing or a deterring influence on them. It is this aspect of the problem which has been particularly considered in the present study. We have exclusively used observational data derived from the records of the Solar Physics Observatory, Kodaikanal. Daily photographs of prominences in the calcium K line taken with a Cambridge spectroheliograph are available at this observatory from the year 1905 onwards. From these, the profile areas of prominences are measured in square minutes and tabulated for each month. The numeration of prominences is admittedly an arbitrary procedure and there must often be a great deal of uncertainty as to whether a prominence is one or several. For this reason the profile areas of prominences have been considered to be a more reliable measure of prominence activity than the numbers, and accordingly this investigation confines itself to the data of the areas of prominences for the period (1913-37).*

TABLE I

Mean daily areas of prominences in square minutes

Year	Jan.	Feb.	Mar.	Apr	May	Jun	Jul	Aug.	Sep	Oct	Nov.	Dec.
1913	2·03	2·77	2·77	2·35	1·91	1·65	1·93	1·44	1·95	1·71	1·94	2·13
14	3·09	3·78	2·15	3·00	2·65	2·98	2·27	3·35	2·55	3·06	3·76	4·47
15	4·37	3·89	7·07	6·08	5·64	3·82	3·65	6·02	4·82	6·68	4·45	4·22
16	5·08	3·88	2·93	3·02	3·63	3·65	2·90	3·18	2·96	3·09	3·97	5·62
17	4·04	6·68	5·43	5·39	5·04	4·35	4·10	5·52	3·60	4·45	6·45	5·43
18	6·15	4·91	5·59	4·56	3·77	4·06	4·37	3·68	3·13	2·00	2·41	2·54
19	3·02	3·46	3·69	3·77	3·39	2·66	3·76	3·63	3·82	4·51	4·15	4·27
20	4·37	3·86	4·39	4·70	4·83	3·70	3·08	3·31	4·16	4·83	4·30	5·42
21	4·74	5·37	4·61	4·90	4·63	3·32	3·25	2·82	4·05	3·96	3·75	3·46
22	2·99	3·21	3·45	3·68	3·07	·46	2·93	2·25	2·05	2·56	3·74	4·74
23	5·30	5·00	4·65	4·73	3·90	3·90	4·20	3·40	4·10	4·10	5·00	3·94
24	5·40	5·66	4·43	4·67	4·20	5·10	4·70	5·00	4·60	6·70	6·30	5·40
25	5·03	5·26	4·49	4·80	5·60	7·10	6·40	5·50	6·30	7·70	7·80	7·84
26	8·76	8·40	9·13	7·04	7·90	7·80	6·30	0·10	8·00	7·70	7·69	7·03
27	8·20	7·00	8·16	7·80	7·50	7·80	7·20	5·20	6·00	5·10	4·35	5·64
28	5·97	6·40	8·39	7·70	8·40	5·00	7·20	7·10	8·20	7·10	8·13	5·47
29	7·22	6·24	6·38	3·70	·80	2·00	3·40	3·90	6·20	5·00	6·04	5·64
30	5·10	5·60	4·89	5·39	6·30	4·20	3·80	2·60	2·90	3·70	2·71	4·10
31	4·20	4·77	4·19	4·30	4·40	3·50	4·40	4·70	4·50	4·90	3·24	2·76
32	3·00	3·00	3·10	2·52	2·10	2·00	1·80	1·60	1·80	1·50	1·71	2·00
33	2·10	1·70	1·92	2·73	2·20	2·40	2·80	1·80	2·20	2·50	3·02	2·44
34	2·70	3·10	2·70	3·65	5·10	4·10	5·50	4·20	4·10	3·70	3·86	3·04
35	4·40	4·50	4·50	4·60	4·70	4·50	4·60	5·10	5·60	3·10	6·16	6·15
36	7·28	6·83	6·24	7·26	7·95	6·37	4·97	5·61	7·34	8·12	10·14	7·13
37	8·27	8·27	7·01	6·95	7·91	5·40	6·50	7·59	6·69	7·34	5·30	6·09
Mean	4·98	1·94	4·89	4·81	4·78	4·25	4·24	4·30	4·50	4·64	4·82	4·72

* We have not made use of the data available for the period 1905-12 for reasons given later in this paper.

In Table I are given the mean daily areas of prominences for each month of the year for the period 1913-37 and the means for the whole period are given in the last row of the table. The mean daily areas have been derived by dividing the total areas of prominences measured from the photographs for the month by the number of effective days in the month. The effective days have been calculated by giving suitable weights to the photographs taken on days of bad observing conditions according to their quality. The photographs taken on days of bad observing conditions have their effective days estimated as $\frac{3}{4}$, $\frac{1}{2}$ or $\frac{1}{4}$ of a perfect day of observation according to the quality of the sky and the definition at the time of the photograph. This procedure of allowing for unfavourable weather conditions has been followed at the Kodaikanal Observatory for many years and has proved to be a satisfactory method of arriving at reliable daily areas of prominences and of dark markings.§

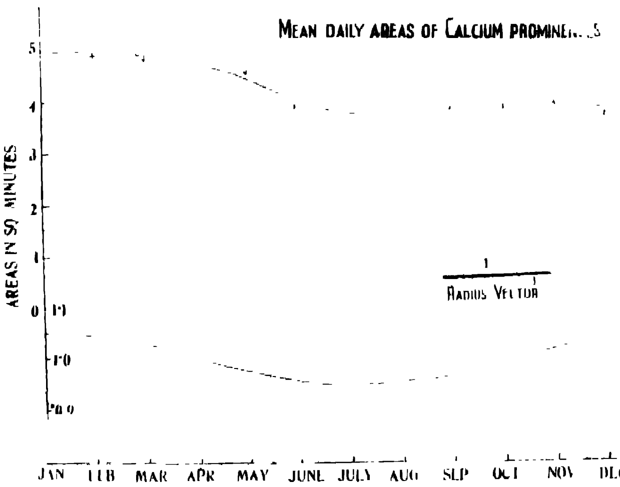


FIGURE 1

The means of Table I are represented diagrammatically in Fig. 1 from which it is evident that the maximum occurs in January and the minimum in July. This suggests that the earth enhances the areas of prominences in January when it is at perihelion and decreases them in July when it is at aphelion. A similar

§ From the year 1923, under the auspices of the International Astronomical Union whenever daily photographs are incomplete or wanting at Kodaikanal, photographs are obtained from other observatories, such as Meudon, Paris, Mt Wilson, Cambridge, etc., for completing the records. Owing to the monsoon conditions prevailing at Kodaikanal during the second half of the year a larger number of photographs from abroad is obtained for that half of the year than for the first half. It is found that the incorporation of the supplementary data derived from the photographs supplied by the co-operating observatories does not alter to any appreciable extent the values of the mean daily areas obtained from Kodaikanal records alone by the method indicated above.

TABLE II

	A	B	C	A_1	B_1	C_1			
Year.	Mean daily areas in Decr. & Jany. in sq. mms.	Daily areas —the mean $(x-\bar{x})$	$(x-\bar{x})^2$	Mean daily areas in June & July in sq. mms.	Daily areas —the mean $(x_1-\bar{x}_1)$	$(x_1-\bar{x}_1)^2$	$A-A_1$	$\{(A-A_1)-(\overline{A-A_1})\}$	$\{(A-A_1)-(\overline{A-A_1})\}^2$
1913	2·54	−2·36	5·5676	1·78	−2·55	6·5025	+0·76	+0·194	0·0376
14	3·67	−1·23	1·5129	2·72	−1·61	2·5921	+0·95	+0·386	·1490
15	4·74	−0·16	0·0960	3·74	−0·59	0·3481	+1·00	+0·434	·1884
16	5·33	+0·43	0·1849	3·23	−1·10	1·2100	−2·10	+1·534	2·3532
17	5·21	+0·31	0·0961	4·22	−0·11	0·0121	+0·99	+0·424	·1798
18	4·59	−0·31	0·0961	4·52	+0·19	0·0361	+0·07	−0·496	·2461
19	3·59	−1·31	1·7161	3·12	−1·21	1·4641	+0·47	−0·096	·0092
20	4·94	+0·04	0·0160	3·41	−0·92	0·8464	+1·53	+0·964	·9293
21	4·06	−0·84	0·7056	3·29	−1·04	1·0816	+0·77	+0·204	·0415
22	3·88	−1·02	1·0204	2·65	−1·68	2·8224	−1·23	+0·664	·4409
23	4·96	+0·06	0·0360	4·07	−0·26	0·0676	+0·89	+0·324	·1050
24	5·40	+0·50	0·0250	4·93	+0·60	0·3600	+0·47	−0·096	·0092
25	6·28	+1·38	1·9044	6·78	+2·45	6·0025	−0·50	−0·066	·0044
26	8·22	+3·32	11·0224	7·11	+2·78	7·7284	+1·11	+0·544	·2959
27	6·91	+2·01	4·0401	7·54	+3·21	10·3041	−0·63	+0·064	·0041
28	5·73	+0·83	0·6889	6·63	+2·30	5·2900	−0·90	+0·334	·1116
29	6·54	+1·64	2·6896	3·14	−1·19	1·4161	+3·40	+2·834	8·0316
30	5·00	+0·10	0·0100	3·98	−0·35	0·1225	+1·02	+0·454	·2062
31	3·63	−1·27	1·6129	3·90	−0·43	0·1849	−0·27	−0·296	·0876
32	2·54	−2·36	5·5696	1·93	−2·40	5·7600	+0·61	+0·044	·0019
33	2·26	−2·64	6·9696	2·60	−1·73	2·9929	−0·34	−0·226	·0511
34	2·89	−2·01	4·0401	4·87	+0·54	0·2916	−1·98	−1·414	1·9993
35	5·20	+0·30	0·0900	4·55	+0·22	0·0484	+0·65	+0·084	·0071
36	7·23	+2·33	5·4289	5·72	+1·39	1·9321	+1·51	+0·944	·8911
37	7·12	+2·22	4·9284	7·88	+3·55	12·6025	−0·76	−0·194	·0376
Mean	$\bar{x}=4·902$		60·09	$\bar{x}_1=4·332$		+71·695	$\overline{A-A_1}=+0·566$		+16·4188

result was obtained by Evershed [3] who found a greater excess of eastern preponderance in the case of prominence numbers and areas measured at perihelion than at aphelion; but he apparently did not attach much significance to this observation presumably because he thought that the small order of difference found by him might be due to bad observing conditions obtaining at Kodaikanal during the south-west monsoon period. This doubt may have been justifiable in the case of the smaller amount of observational material Mr. Evershed had at his disposal and also his method of treatment of the problem; but the larger amount of data used in the present study and the method here employed scarcely leave any room for doubt that the maximum in January and the minimum in July shewn in fig. 1 may be due to the influence of varying observing conditions. The data used in this statistical work extend over a period of twenty-five years, which is a fairly long period, but still it seems desirable to ascertain what degree of reliance can be placed on the conclusions drawn from the data used. For this purpose we have made use of Fisher's[*] "'t' significance test." The means of the grouped values given in Table II fulfil the "t" significance test as shewn below :—

$\bar{x} = 4{\cdot}902$	$\bar{x}_1 = 4{\cdot}332$
$\dfrac{s^2}{n} = \dfrac{\Sigma(x-\bar{x})^2}{n(n-1)}$	$s = 1{\cdot}729$
$s = 1{\cdot}581$	$t = \bar{x}_1 \sqrt{n_1}/s$
$t = \dfrac{4{\cdot}902\sqrt{25}}{1{\cdot}581}$	$= \dfrac{4{\cdot}332 \times 5}{1{\cdot}729}$
$= 15{\cdot}5$	$= 12{\cdot}50$
$P = <{\cdot}01$	$P = <{\cdot}01$

From the table of "t" values it is found that for both the means where n is equal to 25 observations the high values of t show a P-value of less than ·01 which indicates a high degree of significance. The "t" test applied to the mean of the differences between the daily prominence areas at the two epochs also shows a high degree of significance, the P value being less than ·01 The variation of mean daily areas from the maximum in January to the minimum in July amounts to about 15 per cent. of the maximum. It is to be noted, however, that the earth is at perihelion in the beginning of January and at aphelion in the beginning of July, so that the monthly values of January and July do not exactly represent the earth effect at the two epochs, part of the effect falling within the previous month in each case. We have, therefore, worked out the mean values for the months of December and January and for June and July, the former period (December-January) representing the perihelion epoch and the latter (June-July) the aphelion epoch. The results are collected in Table II. These values should reflect the earth effect at the perihelion and aphelion epochs more truly. It is found that the fall from the maximum to the minimum now works out to be 12 per cent. of the maximum. This difference will be further reduced if allowance is made for the possible error in the estimation of effective days. It has already been described how the days of observation are converted into effective days in order to eliminate the influence of bad observing conditions on the daily means. Since the mean daily areas of prominences are obtained by the use of effective days, any error in the estimation of effective days should introduce a corresponding error in the mean daily values. The extreme error that is likely to enter in the estimation of effective days is ± ¼ of an effective day in an incomplete day of observation, since the days are estimated as ¾, ½ or ¼ of a day. Assuming an error of this order the effective days for each month were recalculated and the means of the mean daily areas of prominences were obtained for the values given in Table II. From the recalculated figures it was found that the difference between the mean areas at perihelion and aphelion periods was reduced to 0·6 per cent of the higher value instead of the 12 per cent. previously obtained. The significant fact, therefore, is that there is still a substantial difference between the values at the two epochs of perihelion and aphelion which has to be accounted for.

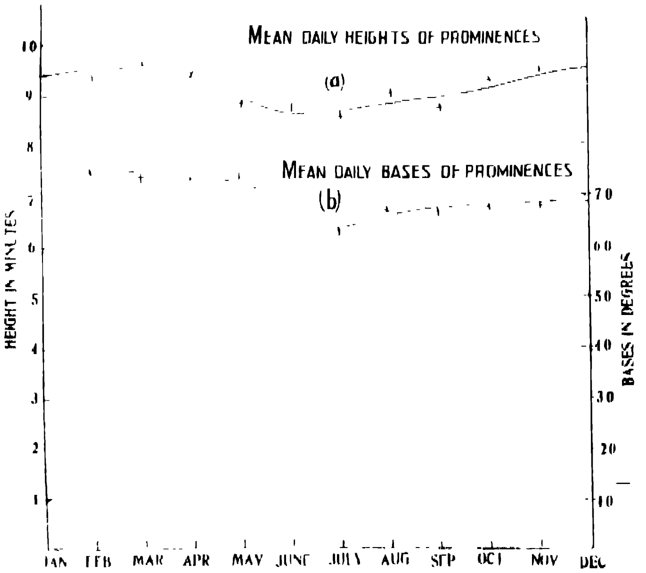


FIGURE 2

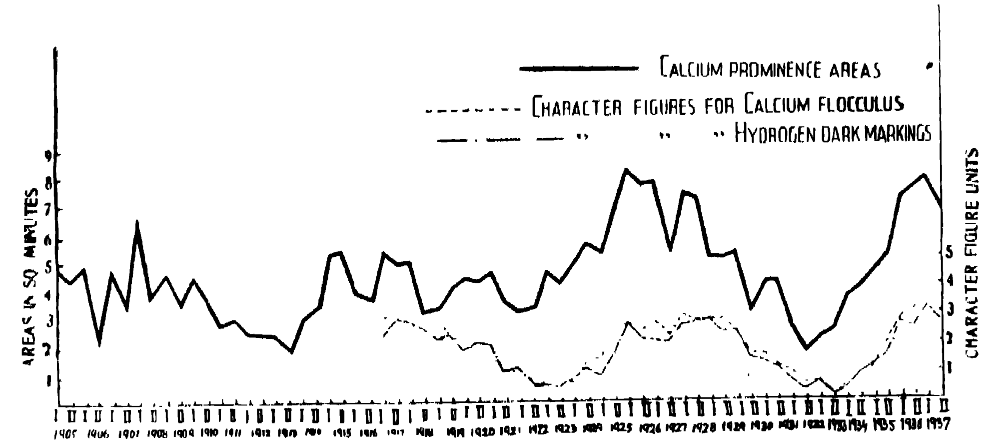
The mean daily heights and bases of prominences derivable from Kodaikanal records were also examined as in the case of the areas. Fig. 2 represents diagrammatically the variations of the mean daily heights and bases from month to month. The resemblance between the curves in Fig. 2 and that in Fig. 1 is quite close. Thus it is evident that the annual variations of all the three elements of solar prominences correspond to the annual variation of the relative distance between the earth and the sun. We now proceed to consider how far this correspondence can be regarded as being due to the influence of the earth alone.

INFLUENCE OF OTHER PLANETS

If the earth is supposed to have an effect on solar phenomena it is to be expected that the other planets may also exercise similar influences. Evershed [3] has shown that of the major planets Venus alone shows an effect similar to that of the earth. On the other hand Royds and Sitaramaiyar [4] state that they do not find any effect of planets or even of the earth on the distribution of numbers of prominences on the east and the west limbs of the sun. Without attempting to reconcile these conflicting views we may take it that, if there is any planetary influence, the greatest positive effect would occur for the outer planets when at opposition and the greatest negative effect when in conjunction with the sun, while for the inner planets the greatest positive effect would occur when at the inferior conjunction and the greatest negative effect when at the superior conjunction. On this assumption the positive and negative effects of the planets on prominence areas at perihelion and aphelion can be calculated from the planetary phenomena occurring near about these epochs. From an examination of planetary phenomena during the years 1913-37 we find that in the months of December and January there occur 3 oppositions and 4 conjunctions of Jupiter, 15 inferior and 12 superior conjunctions of Mercury, while in June and July 5 oppositions and 4 conjunctions of Jupiter, 12 inferior and 14 superior conjunctions of Mercury and 3 inferior and 3 superior conjunctions of Venus occur. If suitable weights according to the tidal force (*vide* Table III quoted from Kodaikanal Observatory Bulletin No. XXXV which gives the different measures of the relative influence of planets on the sun which may be considered) are given to the positive and negative effects it is found that the influences of planets other than the earth at the two epochs are practically equal. The planetary influence does not therefore affect to any appreciable extent the observed difference between the perihelion and aphelion values of prominence areas, which may consequently be taken to represent almost entirely the influence of the earth. In this connection we may note that the planetary phenomena occurring from October to January show that their effect is greater in November than in December; this may be responsible for inflating the values of mean areas of prominences in November over those of December as can be seen from Table I. We do not however advance this as the only explanation of the peculiarity of the November figures;—although we consider it to be very probable that prominence areas are affected by the other planets according to their positions favourable or otherwise with reference to the earth, we do not think it possible to determine with any certainty the effect of the planets on prominences from the measures of prominence photographs taken from the earth, as the effect is likely to be masked by the predominating effect of the earth.

TABLE III

Planets	Effect $\propto M/d$	$\propto M/d^2$	$\propto M/d^3$ (Tidal)	$\propto M/d^4$
Mercury	0·14	0·37	0·95	2·44
Venus	1·12	1·54	2·13	2·95
Earth	1·00	1·00	1·00	1·00
Mars	0·07	0·05	0·03	0·02
Jupiter	60·45	11·62	2·23	0·43
Saturn	9·86	1·03	0·11	0·01



FIGURE

Effect of Variations of Solar Activity on Prominence Data

A diagrammatic representation of the mean daily areas for each half-year for the period (1905-37) (Fig. 3) shows that the values are higher for the first half of the year than for the second half consistently during the period 1905-12 and thereafter the variation of the values is random. This peculiarity suggested that the whole series of prominence observations from 1905 to 1937 was not uniform and it could be split up into two periods, one extending from 1905 to 1912 and the other from 1913 to 1937. Owing to their non-uniformity both the periods could not be combined for this investigation and the data for the shorter period were not used. The data actually made use of did not suggest the existence of any vitiating influence which might introduce any systematic error; nevertheless it was thought desirable to subject them to further scrutiny in order to see whether the observed variations were due to the variations of solar activity or to any other cause. The Bulletin of Character Figures of solar phenomena published by the International Astronomical Union gives the character figures for each solar phenomenon, such as sunspots, calcium flocculi, hydrogen flocculi, etc., for each month of the year from the year 1917 onwards. These character figures represent the index of solar activity for the concerned solar phenomena In the absence of character figures for calcium prominences the figures for calcium and hydrogen flocculi were chosen and the values for each half-year were plotted alongside the prominence areas for the period 1917-37. From the general agreement of the three curves it can be inferred that the variations of mean areas from half-year to half-year reflect only the variations in solar activity. The variations of prominence areas during the earlier period could not be tested for lack of character figures data

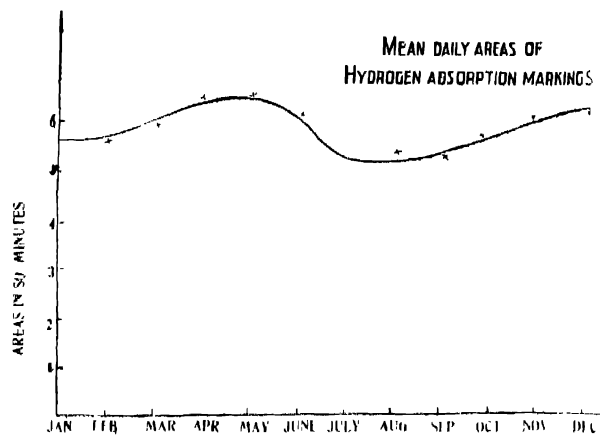


FIGURE 4

Behaviour of Absorption Markings in relation to Earth Effect

As it has been established that the absorption markings are the projections of the overlying prominences on the disc, it is of interest to examine whether the earth influence noticed in prominences is equally observable in the case of the hydrogen absorption markings. Table IV gives the mean daily areas for each month of the hydrogen absorption markings for the years 1917-37 with the exception of 1922. Figure 4 shews the distribution of mean areas from month to month. The trends of the curves in figure 1 and figure 4 are by no means similar. In Figure 4 there are two maxima and two minima,

TABLE IV

Mean daily areas of Hydrogen absorption markings in square minutes

Year	Jan	Feb	Mar.	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct	Nov.	Dec
1917	3·34	4·15	4·65	3·72	5·20	4·49	4·93	6·44	5·18	6·06	6·67	6·6[illegible]
18	5·77	4·06	5·73	6·23	6·69	10·30	3·42	5·18	4·99	4·64	6·79	7·[illegible]
19	5·39	3·58	7·46	6·44	6·87	3·40	6·26	4·41	5·80	5·10	8·00	5·5[illegible]
20	6·76	6·02	4·42	0·80	6·84	9·64	5·20	11·72	5·31	8·75	5·40	11·95
21	6·10	4·73	11·60	4·27	7·10	13·12	2·25	5·30	5·25	3·02	4·60	3·03
22	—	—	—	—	—	—	—	—	—	—	—	—
23	2·19	2·12	1·82	1·64	0·08	0·80	0·52	0·41	0·68	2·60	2·05	3·20
24	2·70	2·40	2·65	1·95	2·10	3·10	5·00	4·50	3·80	5·36	3·20	2·70
25	3·44	2·23	2·90	2·72	3·84	3·02	3·05	4·00	5·64	5·60	6·60	5·73
26	8·00	12·10	10·07	10·02	8·00	5·87	6·70	6·53	5·24	4·60	5·49	7·30
27	5·90	6·75	5·57	10·70	8·40	4·00	5·30	4·40	5·01	5·30	5·60	4·23
28	4·80	5·00	5·00	6·21	6·38	8·35	7·32	5·97	8·26	7·15	8·03	7·20
29	9·00	8·58	7·05	7·91	4·64	4·80	5·43	5·85	6·39	6·56	7·08	7·28
30	6·81	5·40	6·81	7·37	7·34	5·65	5·01	3·85	3·01	2·71	3·92	5·26
31	2·74	2·47	2·90	3·89	4·41	4·08	3·36	3·25	3·10	4·15	3·14	2·49
32	2·42	3·41	2·65	3·02	1·91	1·95	1·97	1·75	1·29	1·05	0·60	1·27
33	1·80	1·64	2·16	2·27	2·13	1·96	1·04	1·66	1·37	1·02	1·14	0·90
34	0·91	1·70	1·62	2·93	3·66	4·08	4·04	3·05	4·15	3·65	5·80	3·64
35	3·56	3·18	5·93	7·40	7·39	5·92	7·84	7·32	7·10	10·50	10·03	12·90
36	12·31	15·60	12·40	17·06	18·90	13·20	12·00	11·80	12·00	15·10	17·11	13·71
37	19·02	17·82	16·48	15·20	17·00	14·41	13·38	13·55	14·10	12·23	11·55	13·10
Mean for 20 yrs.	5·58	5·65	5·90	6·44	6·49	6·10	5·25	5·46	5·40	5·79	6·19	·266

and though the primary minimum occurs in July, the primary maximum occurs in April-May. It seems possible that this behaviour of the Hα dark markings may be due to complications introduced by the semi-annual periodic variation of the heliographic latitude of the earth which ought to have an influence on the markings. In fact, there should be a semi-annual variation in the mean areas of the markings in the northern and southern hemispheres according as the position of the earth varies from north to south or *vice versa*. This aspect of the problem has been discussed by Evershed and Chidambara Iyer[7]. The areas of markings in the northern and southern hemispheres were therefore worked out separately and the distributions in the different months of the year for each hemisphere were plotted in curves. The distribution of areas in the southern hemisphere was found to agree with the theoretical curve, but there was no agreement between the observed distribution and the theoretical curve in the northern hemisphere. A similar separation of areas of prominences between the northern and southern hemispheres was made and the distribution in both the hemispheres was found to be similar to that represented in figure 1 and not to the theoretical curves showing the combined effects of the earth's orbital motion and the variation of the heliographic latitude of the earth in the course of the year. It was therefore concluded that the variation of heliographic latitude of the earth has no effect on the areas of prominences, while it may have some effect on the markings but that effect is not adequate to explain the peculiarities of the distribution of the areas as shown in figure 4.

The dissimilarity in the annual variation of the areas of prominences and of the areas of dark markings should not be taken to signify that there is an intrinsic difference between the behaviours of prominences at the limb and prominences on the disc in regard to the earth effect here considered. The cause of the apparent disparity most probably lies in the inherent indefiniteness of the quantity we call the area of a dark marking. The areas of all prominences at the limb are measured under identical conditions, namely in a plane at right angles to the surface of the sun, and therefore the mean daily areas derived from them are definite quantities. The areas of dark markings, on the other hand, depend upon the longitudes at which they exist as well as on other variable factors; consequently the mean area of dark markings for any given day is derived from measures made under various conditions which introduce a good deal of indefiniteness in the value of the daily mean area. This indefiniteness is further accentuated by the existing practice of applying foreshortening corrections of doubtful applicability, for in the course of its passage across the disc a dark marking presents an intricately varying area, which depends not only upon the variation of the projection of the height of the prominence concerned but also upon other variables; in no position on the disc does the area of a dark marking have a definite relation to the area of the corresponding prominence at the limb. One can easily recognise several other aspects in which the area of a dark marking accessible to measurement is quite unsuitable, compared to the area of the corresponding prominence at the limb, as an index of earth effect. For example, the volume of matter existing as prominences over the whole disc including the limb at any epoch and particularly its annual variation should furnish a reliable clue for the detection of an earth influence. Since the depth of a prominence is small compared to its height and base, the areas of prominences at the limb give a fairly dependable indication of the volume of matter existing as prominences. The areas of dark markings, on the other hand, can give no such reliable indication of the amount of matter existing as prominences on the disc ; for, as Royds has shown, only a fraction of the total quantity of prominence matter absorbs the radiation from the photosphere, the effective part of a prominence in the production of a dark marking being a layer extending from a height of 28 sec. to 33 sec. which may be cool enough to absorb photospheric light. It is also a fact of common observation that all prominences which are observed at the limb do not give rise to dark markings on the disc. It is clear therefore that the mean daily areas of dark markings cannot be as good an index of the volume of matter existing as prominences on the day concerned as the mean daily areas of prominences at the limb. For the reasons enumerated above it is evident that one can scarcely expect to find a similarity of distribution between the areas of prominences and of absorption markings during the different months of the year.

Cause of Earth's Influence

So far it has been our object to establish that there is a genuine influence of the earth on solar prominences. We now proceed to consider the cause of this phenomenon. The mean distance of the earth from the sun is 92 million miles and the difference between the distances at perihelion and aphelion is about 3 million miles. The distances between the earth and the sun at perihelion and aphelion may be taken to be approximately 90.5 and 93.5 million miles respectively. If the earth effect varies directly as its mass and inversely as some power of the distance, the ratio of the effects at the two epochs of perihelion and aphelion varies inversely as the ratio of the powers of the distances. If d_1 and d_2 and r_1 and r_2 represent the distances and the mean daily areas of prominences at perihelion and aphelion respectively, the ratio of the earth effects on prominence areas at the two epochs is given by

$$r_2/r_1 = d_1/d_2 \text{ or } d_1^2/d_2^2 \text{ or } d_1^3/d_2^3 \text{ or } d_1^4/d_2^4 \quad - \quad \text{etc.}$$

$$\text{or } \frac{4{\cdot}332}{4{\cdot}902} = \frac{90.5}{93{\cdot}5} \text{ or } \frac{(90.5)^2}{(93.5)^2} \text{ or } \frac{(90.5)^3}{(93.5)^3} \text{ or } \frac{(90.5)^4}{(93.5)^4} \quad \text{etc.}$$

$$\text{or } {\cdot}884 \quad {\cdot}969 \quad {\cdot}937 \quad {\cdot}907 \quad {\cdot}877 \quad \text{etc.}$$

The ratio r_2/r_1 lies between ·907, and ·877, which shows that the earth effect actually observed varies inversely as some power of the distance intermediate between the third and the fourth. Although this does not justify the conclusion that the earth effect on solar prominences which emerges from the present study is an entirely tidal effect, it would appear that the magnitude of this effect could be accounted for by tidal force with fair approximation.

In conclusion we may mention that the majority of the previous workers ave found a suppressing influence of the earth on solar prominences whereas Evershed and Chidambaraiyar have found evidence for the earth exciting an nhancing influence. The result of the present investigation gives further evidence in support of the latter view.

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